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TECHNICAL MEMORANDUM

TO: Katrina Higgins-Coltrain, EPA Region 6

FROM: Melissa Beauchemin, Ecological Risk Assessor

SUBJECT: Development of Preliminary Remediation Goals for the Wilcox Oil Company Superfund Site, Bristow, Creek County, Oklahoma

The following memorandum discusses the derivation of Preliminary Remediation Goals (PRGs) for the Wilcox Oil Company Superfund Site.

1. SLERA RESULTS

EA conducted a Screening Level Ecological Risk Assessment (SLERA) in January 2020 following Steps 1 and 2 of EPA's Ecological Risk Assessment Guidance (EPA 1997, 1998). The SLERA used conservative assumptions, including conservative toxicity reference values (TRVs) and input parameters for food web models (e.g., 100% site use, 100% earthworm ingestion, etc.). The evaluation also assumed maximum exposure scenarios (e.g., maximum ingestion rates and exposure point concentrations [EPCs]). Modifications were conducted as part of Step 3 of the ecological risk assessment (ERA) process that used more realistic EPCs (i.e., 95th percent upper confidence limit of the mean of the data [95UCL]) and incorporated lowest effect level TRVs. Despite the modifications, the SLERA identified potential risks (based on hazard quotients [HQs] greater than 1) for the following receptors and constituents of potential ecological concern (COPECs), per Table 8-1 in the SLERA:

Area	Receptor	COPEC (HQ_{95UCL})
Wilcox and Lorraine Process Area	Plants	Chromium (9) Copper (3) Lead (3) Vanadium (7) Zinc (3)
	Soil Invertebrates	Chromium (22) Chromium VI (3) Copper (3) Mercury (2) Zinc (4) Isopropylbenzene (4) Xylenes (3)
	Insectivorous Mammals	Lead (2)
	Insectivorous Birds	Lead (9) Vanadium (5)
	Herbivorous Birds	Lead (3)

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Tank Farm and Loading Dock Area	Plants	Chromium (8) Manganese (2) Vanadium (6)
	Soil Invertebrates	Chromium (20) Isopropylbenzene (80)
	Insectivorous Birds	Lead (2) Vanadium (4)
Ponds	Aquatic Organisms	Cadmium (27) Lead (10) Benzo(a)pyrene (4)
Streams	Benthic Invertebrates	Total PAHs (4)
	Aquatic Organisms	Manganese (4)
Note: HQs in parentheses are based on 95UCLs, not maximum concentrations.		

2. SLERA REFINEMENT – LOWER TROPHIC LEVEL ORGANISMS

The following section discusses COPECs for lower trophic level receptors (e.g., benthic invertebrates, plants, and soil invertebrates) that had SLERA HQs greater than 1 based on 95UCLs.

2.1 Total PAHs

Concentrations of Total PAHs in stream sediment, when compared to the probable effects level (PEL) of 16.8 mg/kg (MacDonald et al 1996) instead of threshold effects level (TEL) of 1.68 mg/kg used in the SLERA, indicates no potential risk to benthic organisms from total PAHs in stream sediments.

2.2 VOCs

VOCs such as isopropylbenzene and xylenes were sporadically detected in soil at the site. No direct toxicological studies have been published related to these compounds, and the Region 4 soil screening values (EPA 2018) used to identify COPECs were generated from theoretical structure-activity relations (SAR) using the EPA ECOSAR program to generate water values which may result in toxicity to aquatic organisms. The assumption was made that soil invertebrates are equivalent to sediment invertebrates so that partitioning of the chemicals to organic carbon (assuming 1% organic carbon) was used to generate the risk screening values of 0.04 mg/kg and 0.1 mg/kg for isopropylbenzene and total xylenes respectively. Because of infrequent detection, volatile nature of the chemicals, absence of direct toxicological studies, and the unsubstantiated theoretical nature of the soil screening values, it is not expected that these COPECs would result in unacceptable risk to populations of soil invertebrates; therefore no PRGs have been derived.

2.3 Metals

Where potential risks exist for multiple endpoints (e.g., lower and upper-trophic level organisms), PRGs for metals are not based upon lower-trophic level receptors such as plant and soil invertebrates, but rather on upper-trophic level wildlife instead. There is a paucity of toxicological data in the literature for soil invertebrates and plants and soil screening numbers are generally developed to be extremely conservative. The purpose of using screening values such as EcoSSLs is to provide a conservative prediction of potential risk so that areas that may present potential risk are not overlooked. This is different than soil clean-up levels or PRGs which are designed for risk management and consider more realistic and site-specific exposure and toxicity scenarios.

The SLERA Results Table provided above shows that HQs for plants and soil invertebrates from metals impacts are generally low. Some locations with elevated concentrations that are driving the EPCs are co-located with high concentrations of lead and/or benzo(a)pyrene that are targeted for removal, particularly in the Process Areas. Therefore, post-removal concentrations of many metals across the Process Areas will be lower, reducing the HQs even further.

Scattered elevated concentrations of some metals (e.g., manganese) are located in the North Tank Farm in areas of re-worked soil and sand along the gas pipeline that are used for storage of various materials. These areas have been cleared of vegetation and are continuously used for industrial purposes. As such, they lack sufficient quality habitat for ecological receptors. Sporadic elevated concentrations of metals also occurring in the East Tank Farm are likely anomalies and not linked to any recent or historical on-site activities. These areas are also void of vegetative cover due to residential and agricultural uses and therefore provide insufficient habitat for ecological receptors. Test-pitting conducted in the vicinity of elevated metals concentrations at the Tank Farms did not indicate any major waste items or residual process materials that could be linked to these metals.

In addition, sporadic elevated concentrations of metals in soil would not necessarily be toxic to entire populations of plants and/or invertebrates. In fact, many plants are tolerant of high concentrations of metals and will accumulate significant concentrations of metals without demonstrating any adverse effects. Because of plants' ability to accumulate concentrations of metals, they are often used for phytoremediation. For example, Efroymson et al. (1997a) notes that four plant studies showed no adverse effects to plants with lead concentrations in soil of at least 100 mg/kg and even up to 500 mg/kg of lead. In several instances, effects were not observed until lead concentrations in soil were 500 to 1,000 mg/kg. A recent phytotoxicity study by Cheyns et al. (2012) revealed no impacts to tomato and barley plants until lead concentrations in soil reached 1,600 mg/kg for tomatoes and 1,900 mg/kg for barley, at which point growth impacts were observed.

There is a lack of general toxicity from many metals (e.g., copper, manganese, zinc) which are essential elements for all living organisms and are naturally occurring, sometimes at high concentrations. Thus, there is unlikely to be adverse effects on soil invertebrates or plants from these metals. Elevated concentrations of these metals on site are sporadic and unlikely to impact entire populations. In addition, aging/weathering reduces the bioavailable fraction of metals in soil over time (EPA 2007a). Processing activities ended in the 1960s, thus much of the metallic residues are likely tightly bound to soils due to weathering, aging, and other natural processes. No instances of plant toxicity have been observed on site. In their bioavailable forms, these metals are easily taken up by soil invertebrates, particularly earthworms, which are capable of regulating uptake and storage of metals. In fact, uptake by soil invertebrates is nonlinear and decreases as soil concentration increases (EPA 2007a). Availability of contaminants for uptake by earthworms is controlled by soil characteristics such as grain size, pH, organic carbon content, and moisture content (Efroymson et al. 1997b).

Copper, manganese, and zinc are essential nutrients in plants and important in oxidation, photosynthesis, and protein and carbohydrate metabolism. Copper deficiency is demonstrated by wilting leaves, melanism, and white twisted tips (EPA 2007b). In its soluble form, manganese is taken up by plants and rapidly distributed throughout the plant. Manganese toxicity in plants is demonstrated by iron chlorosis, leaf puckering, necrotic brown spots, and an uneven distribution of chlorophyll in older leaves (EPA 2007c). Toxicity data used to develop EPA's EcoSSL for plants indicates some plants (e.g., cotton and nile grass) did not show adverse impacts to growth until manganese concentrations in the soil reached 707 mg/kg (EPA 2007c).

Zinc is expected to demonstrate low mobility in most soils and is strongly adsorbed to soils at pH 5 or greater (EPA 2007d). Only those fractions of zinc in soil which are soluble or may be solubilized are bioavailable. Compared to total zinc content of soils, concentrations of zinc in soil solution are low. The solubility of zinc increases at decreasing pH (EPA 2007d). The pH at the site, particularly in the Wilcox Process Area, is neutral to basic with an average pH of around 8. The Lorraine Process Area contains slightly more acidic soils with an average pH of around 6. The pH in both these areas is not low enough to mobilize zinc and increase its bioavailability. In addition, it should also be noted there is little vegetation present in the process areas where the highest concentrations are located.

A search of EPA's Ecotox database indicates zinc toxicity to invertebrates varies greatly, depending on form, soil type, species, pH, organic content, and exposure time. Effects concentrations range from 1.5 to 5,150 mg/kg in springtail, with an average of 806 mg/kg. In plants, zinc is necessary for carbohydrate and protein metabolism. Excess zinc produces iron chlorosis (EPA 2007d). EPA's Ecotox database indicates zinc toxicity to plants varies greatly, with effects values ranging from 5 mg/kg in brown mustard (*Brassica juncea*) to 1,000 mg/kg in field mustard (*Brassica rapa*), with an average of 425 mg/kg. Thus, the EcoSSLs for zinc of 120 mg/kg for plants and 160 mg/kg for soil invertebrates are highly conservative and should only be used for original intended purpose —to screen the data as they are too conservative to be used as cleanup goals.

Due to the lack of adequate toxicity studies, there are no EcoSSLs for chromium or vanadium for soil invertebrates or plants. Only two soil invertebrate studies were identified by EPA in the chromium Eco SSL document (EPA 2008). Although EPCs exceed the screening benchmarks for soil invertebrates and plants, the HQs for mammals and birds are less than 1, indicating that chromium is not accumulating in tissue levels that would cause adverse effects to wildlife. Therefore, chromium in soil does not present potential for adverse ecological effects. There are also no EcoSSL values for mercury. Screening benchmarks used for chromium, vanadium, and mercury were based on Efroymson et al. (1997 a,b). Efroymson et al. (1997a) cautions that their plant benchmarks used in the SLERA are to "serve primarily for contaminant screening." Efroymson et al. (1997b) also cautions that their soil invertebrate benchmarks "are appropriate for contaminant screening purposes only."

In summary, there is unlikely to be adverse impacts to the plant or soil invertebrate communities at the site from sporadic elevated concentrations of metals based on the following:

- Low HQs identified in the SLERA, based solely on a screen against EcoSSLs or screening benchmarks from Efroymson et al. (1997a,b).
- Low potential for uptake and toxicity from naturally occurring metals, many of which are essential nutrients.
- Sporadic elevated concentrations not linked to facility activities.
- Lack of sufficient ecological habitat from long-term and/or continued future industrial, residential, and agricultural usage of many portions of the site.
- Removal of select concentrations of metals during excavations for lead and/or benzo(a)pyrene, thus reducing the overall HQs.

As a result, PRGs were not developed for plants or soil invertebrates. Instead, PRGs have been developed based on potential risks to upper-trophic level receptors (i.e., birds and mammals) which may consume plants and invertebrates. Cleanup levels based on these wildlife species are likely to be protective of populations of lower trophic organisms as well. As such, the food web models were updated for copper, lead, and vanadium to be reflective of more realistic, site-specific conditions in the next section. These refinements are generally conducted during the baseline ecological risk assessment (BERA). Following a refinement of exposure parameters, back-calculated soil concentrations (i.e., PRGs) are developed assuming a HQ of 1 in the food web model.

3. FOOD WEB MODEL REFINEMENT – UPPER TROPHIC LEVEL ORGANISMS

As part of the BERA, food web models can be modified to reflect more realistic and site-specific input parameters. For instance, in the SLERA, to be conservative, the robin was assumed to ingest 100% earthworms; however, robins actually eat a mixed diet that includes both fruits and insects. EPA (1993) indicates that, in the central U.S., robins ingest approximately 50% plants and 50% invertebrates. The revised food web models for lead and vanadium assume a diet of 50% plants and 50% invertebrates. In addition, robins are migratory and will likely reside in the area for only eight months of the year. A seasonal use factor of 0.67 was used for the revised food web models.

The SLERA also assumed the shrew has a soil ingestion rate of 13% based on Sample and Suter (1994). More recent estimates of soil ingestion for the shrew based on EPA’s EcoSSL documents (EPA 2007e) indicate that their soil ingestion rate is only approximately 3%. The soil ingestion rate of 3% was used in the revised food web model. Furthermore, EPA (1993) indicates that shrews also ingest some plant tissue (approximately 17% of their diet) as well as mammals (approximately 5% of their diet). As such, the dietary composition for the shrew was updated to 78% invertebrates, 17% plants, and 5% mammals in the revised food web model.

3.1 Bioaccumulation

Over the past decade, much research has focused on the bioavailability of metals, especially in terms of risk. Only the bioavailable component (species) of metals is capable of uptake by a receptor organism, and therefore, only that portion is capable of eliciting adverse effects. The bioavailability of metals in soil is influenced by the species (forms) present, particle size, organic carbon content, and whether minerals have been encapsulated or coated by other mineral phases. These factors can all influence metal bioavailability, often reducing it to less than 100% (Kaufman et al. 2007).

Bioaccumulation factors (BAFs) for plants and earthworms used in the revised food web models have been updated in the EcoSSL guidance documents (EPA 2007e) as shown below:

COPEC	Plant BAF	Invertebrate BAF
Copper	$\ln(C_{plant}) = (0.669+0.394*\ln(C_{soil}))$	$C_{worm} = C_{soil}$ x 0.515
Lead	$\ln(C_{plant})=(-1.328+0.561*\ln(C_{soil}))$	$\ln(C_{worm}) = (-0.218+0.807*\ln(C_{soil}))$
Vanadium	$C_{plant} = C_{soil}$ x 0.00485	$C_{worm} = C_{soil}$ x 0.042

3.2 Bioaccessibility

In order to pose a risk to an organism, ingested contaminants must be "bioaccessible," meaning they must be able to enter the gastrointestinal tract of the organism and be absorbed into the bloodstream. The quantity of bioaccessible metal available to an organism can be analyzed in the laboratory via *in vitro* methods. Using a synthetic gastric solution consisting of various acids, laboratories are able to distinguish between organic (bioavailable) and inorganic (non-bioavailable) forms of metals, by the quantity of metal extracted or "digested" from the sample. Suedel et al. (2006) showed that the majority of lead in soil at a former refinery was in its inorganic form, with bioaccessibility percentages ranging from 8 to 78%. Incorporating the bioavailability/bioaccessibility factor into the food web models for the ecological risk assessment substantially reduced risk estimates (Suedel et al. 2006).

Kaufman et al. (2007) conducted bioaccessibility models for mammals (eastern cottontail and short-tailed shrew) and birds (American robin) to investigate the proportion of lead mobilized into the digestive juices (i.e., the bioaccessible fraction) from soil, earthworms, and vegetation collected at a rifle and pistol range in Canada. Total lead concentrations averaged 5,044 mg/kg in surface soil, 727 mg/kg in earthworm tissue, and 2,945 mg/kg in unwashed vegetation. For mammalian gastric models, the bioaccessible fraction of lead in soils was 66%, in earthworm tissue it was 77%, and in unwashed vegetation the bioaccessible fraction was 50%. For the avian gastric model, the bioaccessible fraction of lead in soil was 53%, and in earthworm tissue it was 73%.

Kaufman et al. (2007) demonstrated that the incorporation of soil and food web intermediate bioaccessibility data into standard ecological risk calculations results in lower risk estimates for all receptors. Hazard quotients did not exceed 1 for the American robin until soil lead concentrations reached 1,000 mg/kg. The inclusion of bioaccessibility information during ERA provided a more realistic estimate of contaminant exposure and is a valuable tool for use in management of contaminated sites. Using only total metals concentrations can lead to an overestimation of risk and the potential for unwarranted and costly site remediation (Kaufman et al. 2007). As such, the food web models were modified to incorporate a bioaccessibility factor for lead as follows:

Receptor	Media Ingested	Bioaccessibility Factor (B)
Robin	Soil	53%
	Earthworms	73%
	Plants	100%[a]
Shrew	Soil	66%
	Earthworms	77%
	Plants	50%
Sparrow	Soil	53%
	Plants	100%[a]

a. No value identified by Kaufman et al. 2007 so plants assumed to contain lead that is 100% bioaccessibile.

3.3 TRV Refinement

For the development of avian TRVs, the EcoSSL documents for lead (EPA 2005a) and vanadium (EPA 2005b) present a large range of NOAEL and LOAEL TRVs, many of which are based on chickens. Because chickens are bred for agriculture, they have unnaturally high growth and reproduction rates. Furthermore, chickens do not ingest earthworms and should not be used as a surrogate for insectivorous birds. Many of the studies use gavage methods as the route of exposure in the study. This forced feeding causes animals to have much higher ingestion rates than normal foraging on their own.

The toxicity dataset used in the EcoSSL documents to identify TRVs includes studies with medium- or low-level confidence. Studies ranked with a Data Evaluation Score of 80 to 100 have a higher degree of confidence than studies ranked in the 60s (low confidence) or 70s (medium confidence).

For copper, the published EcoSSL TRVs of 4.05 mg/kg-day and 12.1 mg/kg-day were used without modification (EPA 2007b).

3.3.1 Lead

EPA's Eco SSL Document for Lead (EPA 2005a) provides a range of avian TRVs that spans up to six orders of magnitude. NOAEL TRVs based on survival, growth, or reproduction range from 0.194 to 196 mg/kg and LOAEL TRVs range from 0.11 to 625 mg/kg. EPA recommends a NOAEL TRV of 1.63 mg/kg-day and a LOAEL of 3.26 mg/kg from the corresponding study. The NOAEL TRV is based on a study (Edens and Garlich 1983) that used chickens which are an inappropriate receptor because, as mentioned above, they are domestic animals with abnormally high reproduction (i.e., egg-laying) and growth rates. The study was based in the laboratory, not in the field, and therefore is not representative of natural conditions. The study was only four weeks long, which is not a sufficiently long study to identify chronic toxicity values.

Sample et al. (1996) calculated a NOAEL TRV of 3.85 mg/kg-day from a study by Pattee (1984). This study evaluated eggshell thickness in American kestrel (wild bird) which is more representative of ecological receptors in their natural habitat with natural reproduction rates. The study was conducted over a period of six months. Because the study was conducted for more than 10 weeks and during a critical lifestage (eggs), the study is considered chronic. EPA (2005a) ranked the Pattee (1984) study with the highest evaluation score of all the lead-bird studies (value of 90). The Edens and Garlich (1983) study was ranked only at 79. The NOAEL from the same study as calculated by EPA is 12 mg/kg-day (2005a). This discrepancy is likely the result of differing estimated ingestion rates because none was provided in the study. However, EPA (2005a) calculated a geometric mean value of all the NOAELs for avian reproduction and growth to be 10.9 mg/kg-day, which is similar to the NOAEL calculated by EPA (2005a) from the Pattee (1984) study (12 mg/kg-day). As such the recommended avian NOAEL for lead is 3.85 mg/kg. Because there was no LOAEL associated with the study, an uncertainty factor of 10 is applied to estimate the corresponding LOAEL of 38.5 mg/kg. These values were incorporated into the back-calculated food web model to identify a protective lead soil concentration for birds.

3.3.2 Vanadium

For vanadium, the avian TRVs selected in the EcoSSL document (EPA 2005b) are extremely low – the NOAEL is 0.344 and the LOAEL is 0.688 mg/kg. The EcoSSL dataset has NOAELs for growth, reproduction, and survival that range from 0.244 to 98.7 mg/kg. LOAELs range from 0.319 to 14.8 mg/kg. Because many of the studies use chickens and do not have data scores with a high level of confidence, EA sought to calculate a more reasonable TRV. Studies with endpoints for survival, growth, and reproduction with data evaluation scores less than 80 were eliminated. Studies that did not have a bounded NOAEL and LOAEL were also eliminated. This left a total of 26 studies. Although all based on chickens, data evaluation scores ranged from 81 to 90 indicating a high degree of confidence in the results of the studies. Resulting NOAELs ranged from 0.244 to 6.37 mg/kg and LOAELs ranged from 0.413 to 14.8 mg/kg. The geometric mean of the NOAELs is 1.24 mg/kg and the geometric mean of the LOAELs is 2.5 mg/kg. These values were incorporated into the back-calculated food web model to identify a protective vanadium soil concentration for birds.

3.4 Results

Using the modified input parameters identified above, the food web models were set up to back-calculate a protective soil concentration for copper, lead, and vanadium (i.e., equivalent to a HQ of 1). This was done using the following equation:

$$PRG = C_{soil} = \frac{TRV \times BW \times HQ}{SUF \times \{(IR_{soil} \times B_{soil}) + \sum_{i=1}^{n}(IR_{food} \times BAF \times F_{diet} \times B_{food})\}}$$

Where:

PRG = preliminary remediation goal (mg/kg)
C_{soil} = concentration in soil (mg/kg)
TRV = toxicity reference value (mg/kg-bw/day)
BW = body weight (kg)
HQ = hazard quotient (unitless)
SUF = site use factor (unitless)
IR_{soil} = ingestion rate of soil (kg/day)
IR_{food} = ingestion rate of food (kg/day)

BAF = bioaccumulation factor (unitless)
B = bioaccessibility factor for soil and food, respectively (percent)
F_{diet} = fraction of prey (i) in diet
$\sum$ = sum of ingestion for all prey

After the exposure parameters and input values were entered into an Excel spreadsheet and the calculation was considered complete, PRGs were developed using the "What if, Goal seek" data function in Excel. This function sets the cell for the HQ to 1 while changing the soil concentration in the equation. This is conducted for both the NOAEL and LOAEL TRV. Geometric mean-based PRGs are a reasonable balance between no effect and lowest effect toxicity levels (EPA 1999). Therefore, the geometric mean of the two values is selected as the PRG. Attached Tables 1 through 3 present the food web models for robin (insectivorous bird), shrew (insectivorous mammal), and sparrow (herbivorous bird), respectively. The following table summarizes the PRGs:

COPEC	**Back-Calculated PRG (mg/kg)**	**Receptor**
Copper	**285**	Herbivorous Bird
Lead	**204**	Insectivorous Mammal
	441	Insectivorous Bird
	907	Herbivorous Bird
Vanadium	**66**	Insectivorous Bird

4. BACKGROUND

Background values are also considered because CERCLA does not cleanup to levels below background (EPA 2002). Two background datasets are available, including a site-specific background upper prediction limit (UPL) that was calculated as part of the SLERA as well as regional (Oklahoma) soil background values from the EcoSSL documents (EPA 2007e). Background values for these constituents are lower than the PRGs, as noted below:

COPEC	**UPL (mg/kg)**	**Regional OK Background (mg/kg)**	**Final PRG (mg/kg)**	**Basis**
Copper	3.24	15.9	285	Herbivorous Bird
Lead	9.19	17.6	204	Insectivorous Mammal
Vanadium	11.17	50	66	Insectivorous Bird

5. AQUATIC ORGANISMS

Potential risks to aquatic organisms in the ponds and streams from elevated concentrations of constituents in the water column are likely to be reduced following removal of contaminated soil in the upland. Because sediment in these areas is not impacted and there is no need for sediment removal, water quality monitoring may be necessary to ensure that water column concentrations decrease following soil removal activities.

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Tables

Tables

Preliminary Remediation Goals for American robin

LOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Inverts	Bioaccessibility Soil	Dietary Composition (%) Plants	Dietary Composition (%) Inverts	Tissue Concentrations (mg/kg) Plants	Tissue Concentrations (mg/kg) Inverts	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) LOAEL	PRG (mg/kg) LOAEL	HQ
Lead	0.077	0.67	1.00	0.73	0.53	50%	50%	17	314	0.0171	0.0018	38.49	38.5	1627.55	1.00
Vanadium	0.077	0.67	1	1	1	50%	50%	0.452	4	0.0171	0.0018	2.50	2.5	93.09	1.00

NOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Inverts	Bioaccessibility Soil	Dietary Composition (%) Plants	Dietary Composition (%) Inverts	Tissue Concentrations (mg/kg) Plants	Tissue Concentrations (mg/kg) Inverts	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) NOAEL	PRG (mg/kg) NOAEL	HQ
Lead	0.077	0.67	1	0.73	0.53	50%	50%	4	38	0.0171	0.0018	3.85	3.85	119.59	1.00
Vanadium	0.077	0.67	1	1	1	50%	50%	0.22	2	0.0171	0.0018	1.24	1.24	46.17	1.00

	Geomeans	Bkgd
lead	**441**	18
vanadium	**66**	50

Exposure Parameters

	Body Weight	0.077 kg	
Lead	BAFworm	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	EcoSSL
Lead	BAFplant	ln(dry plant conc, mg/kg) = (-1.328+0.561*ln(soil conc))	EcoSSL
Vanadium	BAFworm	4.20E-02	EcoSSL
Vanadium	BAFplant	4.85E-03	EcoSSL
Copper	BAFworm	0.515	EcoSSL
Copper	BAFplant	ln(dry plant conc, mg/kg) = (0.669+0.394*ln(soil conc))	EcoSSL

Bird TRVs	NOAEL	LOAEL	Ref
Lead	3.85	38.5	Sample et al. 1996
copper	4.05	12.1	EcoSSL TRVs
Vanadium	1.24	2.5	self-derived TRVs

Mammal TRVs	NOAEL	LOAEL	
Lead	4.7	8.9	EcoSSL

Food Ingestion Rate	0.22	kg dry wt./kg-day	Converted assuming 75% prey moisture (USACHPPM 2004)
Food Ingestion Rate	0.89	kg wet wt./kg-day	EPA 1993
Incidental Soil Ingest	10.50%	% of total mass of diet	Value based on woodcock (Sample and Suter 1994)

Food ingestion	0.0171325	dry weight	kg/d
Food ingestion	0.06853	wet weight	kg/d
soil ingestion	0.0017989	dry	kg/d

SOUTHERN SHORT-TAILED SHREW

Body Weight	0.017213	kg		
Food Ingestion Rate	0.16	kg dry wt./kg-day	Plants	17%
Food Ingestion Rate	0.62	kg wet wt./kg-day	Inverts	78%
Incidental Soil Ingestion Rate	3.00%	% of total mass of diet	Mammals	5%
FIR	0.00275	kg/d		
SIR	8E-05	kg/d		

Preliminary Remediation Goals for Shrew

LOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility			Dietary Composition (%)			Tissue Concentrations (mg/kg)			Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Dietary Dose (mg/kg-day)	TRV (mg/kg-d)	PRG (mg/kg)	HQ
			Inverts	Soil	Plants	Inverts	Plants	Mammals	Inverts	Plants	Mammals				LOAEL	LOAEL	
Lead	0.017213	1	0.77	0.66	0.50	78%	17%	5%	81	7	13	0.0028	0.0001	8.90	8.9	301.79	1.00

NOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility			Dietary Composition (%)			Tissue Concentrations (mg/kg)			Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Dietary Dose (mg/kg-day)	TRV (mg/kg-d)	PRG (mg/kg)	HQ
			Inverts	Soil	Plants	Inverts	Plants	Mammals	Inverts	Plants	Mammals				NOAEL	NOAEL	
Lead	0.017213	1	0.77	0.66	0.5	78%	17%	5%	43	4	10	0.0028	0.0001	4.70	4.70	138.33	1.00

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SONG SPARROW

Body Weight	0.032	kg	Sherman and Wasser 2010; average weight of song sparrow
Food Ingestion Rate	0.2141	kg dry wt./kg-day	Calculated using allometric equation for birds from Nagy 2001
Food Ingestion Rate	0.8566	kg wet wt./kg-day	Converted assuming 75% prey moisture (USACHPPM 2004)
Incidental Soil Ingestion Rate	9%	% of total mass of diet	Beyer et al 1994, value for turkey

FIR	0.0068512	kg/d
SIR	0.0006166	kg/d

Preliminary Remediation Goals for Song Sparrow

LOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Soil	Dietary Composition (%) Plants	Concentrations (mg/kg) Plants	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) LOAEL	PRG (mg/kg) LOAEL	HQ
Lead	0.032	1	1.0	0.53	100%	25	0.0069	0.0006	38.50	38.5	3250.83	1.00
Copper	0.032	1	1	0.53	100%	25	0.0069	0.0006	12.10	12.1	657.24	1.00

NOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Soil	Dietary Composition (%) Plants	Concentrations (mg/kg) Plants	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) NOAEL	PRG (mg/kg) NOAEL	HQ
Lead	0.032	1	1	0.53	100%	6	0.0069	0.0006	3.85	3.85	253.00	1.00
Copper	0.032	1	1	0.53	100%	13	0.0069	0.0006	4.05	4.05	123.54	1.00

	Geomean
Lead	907
Copper	285